DOCUMENT RESUME

ED 213 860 CE 031 483

TITLE Safety for Compressed Gas and Air Equipment. Module SH-26. Safety and Health.
INSTITUTION Center for Occupational Research and Development, Inc.; Waco, Tex.
SPONS AGENCY Office of Vocational and Adult Education (ED). Washington, DC. Div. of National Vocational Programs.
PUB DATE 81
CONTRACT 300-79-0709
NOTE 39p.; For related documents see CE 031 450-507.
AVAILABLE FROM The Center for Occupational Research and Development, 601 Lake Air Dr., Suite C, Waco, TX 76710 (Instructor Guides, $9.75 each; Learning Modules, $3.00 each. Entire set of Learning Modules available as two subsets: SH-21, SH-41, SH-43, SH-45, and SH-48, $12.00; remaining 45 modules, $97.50).

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Behavioral Objectives; Equipment Utilization; *Health Education; *Learning Activities; Learning Modules; Postsecondary Education; *Safety Education; Secondary Education; *Vocational Education
IDENTIFIERS *Compressed Air Equipment; *Compressed Gas Equipment; Occupational Safety and Health

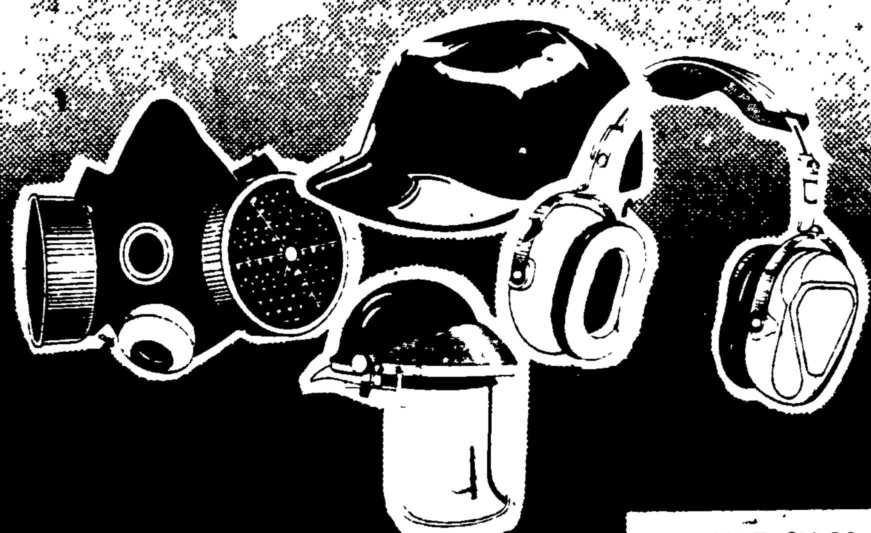
ABSTRACT

This student module on safety for compressed gas and air equipment is one of 50 modules concerned with job safety and health. This module presents technical data about commonly used gases and stresses the procedures necessary for safe handling of compressed gases. Following the introduction, 14 objectives (each keyed to a page in the text) the student is expected to accomplish are listed (e.g., Name the two common methods of transporting gases). Then each objective is taught in detail, sometimes accompanied by illustrations. Learning activities are included. A list of references and answers to learning activities complete the module. (CT)

ED213860

SAFETY AND HEALTH

SAFETY FOR COMPRESSED GAS
AND AIR EQUIPMENT



MODULE SH-26

CE031483

CORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

The activity which is the subject of this document was supported in whole or in part by the U. S. Department of Education. However, the opinions expressed herein do not necessarily reflect the position or policy of the Department of Education, and no official endorsement by the Department of Education should be inferred.

This work was developed under contract number 300790709 for the U. S. Department of Education, Office of Vocational and Adult Education.

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INTRODUCTION

Gases in compressed or liquefied forms play an indispensable role in today's modern technology. These gases are all around us - compressed air for automobile tires, gases used in medical treatment, fertilizers for crop lands, and gases essential to making plastics. Even the comfort of our living quarters depends on a compressed gas (Freon) for heating and cooling.

As the use of compressed gas grows in every area of industry, so does the worker's need for authoritative information on methods for safe handling, control, and use of these gases. Many of these gases are harmful in any state; they are either flammable, toxic, or corrosive. In the compressed state, even nonharmful gases such as air can be hazardous.

The best way to avoid accident and personal injury on the job is to be able to identify the contents of each compressed gas container, to recognize the handling problems that may be expected, and to know the accepted safe methods of use. The final step is to use these accepted procedures in handling compressed gases.

This module presents technical data about commonly used gases and stresses the procedures necessary for safe handling of compressed gases. Examples of typical equipment and safe application for gases are presented; the common oxyacetylene welding process is used as an example of the hazards involved in using compressed gases.

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Name the two common methods of transporting gases. (Page 3)
2. Describe five types of potentially hazardous gases. (Page 4)
3. Identify the differences between low-pressure and high-pressure cylinders as related to use and construction. (Page 7)
4. Describe three types of safety-relief devices for compressed gas cylinders. (Page 11)

5. Identify the hazards encountered in handling compressed gas cylinders on the job and state the safety measures required. (Page 12)
6. Describe the types of cylinder damage and the method and criteria for periodic inspection. (Page 13)
7. Describe the types of storage areas acceptable for safe storage of compressed gas cylinders. (Page 15)
8. Name the types of vehicles and containers that are widely used in the transport of compressed gases. (Page 17)
9. State the classification of gas contained in a cylinder by identifying the DOT label. (Page 18)
10. Explain the effect of heat on gas cylinders and tanks containing flammable gases. (Page 20)
11. Identify the particular hazards of oxygen, acetylene, MAPP gas, natural gas, liquefied petroleum gas, chlorine, ammonia, hydrogen, carbon dioxide, and fluorine. (Page 21)
12. Identify three main hazards associated with cryogens and tell the particular hazards associated with liquid oxygen, liquid fluorine, and liquid nitrogen. (Page 27)
13. Explain the difference between medical-use and industrial-use gases and give five examples of medical uses for gases. (Page 30)
14. Describe the general safety hazards in using compressed air. (Page 31)

OBJECTIVE 1: Name the two common methods of transporting gases.

The materials used by workers in industrial jobs can come in many forms. One way of classifying and referring to materials is by their state of matter - solid, gaseous, or liquid.

Gases are defined as formless fluids that occupy the space of enclosure and that can be changed to the liquid or solid state only by the combined effect of increased pressure and decreased temperature. "Occupy the space of enclosure" simply means that gases will "spread out" to fill up whatever space is available.

Many of the gases being used in industry are manufactured from the air (natural atmosphere) around us by compressing air and removing the heat generated by compression until the air turns to liquid. The composition of air is given in Table 1 below.

TABLE 1. APPROXIMATE COMPOSITION OF DRY AIR.

Component	% of Volume.
Nitrogen	78.03%
Oxygen	20.99%
Argon	0.94%
Carbon Dioxide	0.03%
Hydrogen	0.01%
Neon	0.00123%
Helium	0.0004%
Krypton	0.0005%
Xenon	0.000006%

After the air turns to liquid, the individual gases are produced by controlled reheating (separation of the liquid that allows each gas in the liquid to boil off to a gaseous state at its natural gasification point).

This liquid air process uses enormous amounts of energy and requires expensive machinery. To make the use of gases economically feasible, air reduction facilities must have a safe and manageable way of transporting gases to the consumer.

Whether gases are carried by rail, water, air, or highway, the two common methods of "packaging" for shipment are in the gaseous state, compressed at over 25 pounds per square inch gage (psig) or in the liquid state, in cryogenic containers (containers of very low temperature) at less than 25 psig.

ACTIVITY 1:

(Fill in the blanks.)

1. Compressed gases are those that have been contained at over ________________.
2. Gases can be transported in the ____________ state, in ______________ containers.

> **OBJECTIVE 2:** Describe five types of potentially hazardous gases.

To ensure safe handling and transporting of gases, the gases manufactured from air, as well as other gases, are subdivided by their effects on human beings. The gases are then labeled according to Department of Transportation categories. These categories are explained below.

Flammable gases, when mixed with air, oxygen, or other oxidants, burn or explode (depending upon the degree of confinement) upon ignition. Each flammable gas has a gas-in-oxidant concentration range within the limits of which the gas may be ignited. Flammable ranges are expressed in terms of air at ambient (surrounding) temperature and atmospheric pressure. A change in temperature, pressure, or oxidant concentration may vary the flammable

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*Answers to Activities begin on Page 34.

range considerably. Mixtures above and below the flammable range do not ignite. As a precaution in handling flammables, care must be taken to eliminate all possible sources of ignition through the proper design of facilities, the installation of approved electrical systems, the restriction of smoking, and the prohibition of the use of open flames. An explosimeter should be used to determine the presence of a flammable mixture in areas of suspected leakage. Some examples of flammable gases that workers encounter in industry are acetylene, propane, butane, methylacetylene-propadiene (MAPP), and hydrogen.

A number of gases, although nonflammable, may initiate and support combustion. These gases are known as oxidants. Materials that burn in air, burn more vigorously (even explosively) in oxygen and certain other oxidants. All possible sources of ignition must be eliminated when handling oxidants. Oxidants must not be stored with combustible materials. Oil, grease, or other readily combustible substances must not come in contact with cylinders or equipment used in oxidant services.

Corrosives are those products that erode and deteriorate materials (metals, fabrics, and human tissue) with which they come in contact. Some gases, although not corrosive in their anhydrous (without water) form, become corrosive in the presence of water. Special care must be taken when selecting the proper construction materials for equipment in which corrosives are handled. Gases that do not cause deterioration but do induce inflammation of human tissues are known as irritants. Inflammation of the tissue may occur after immediate, prolonged, or repeated contact with the irritant. Gases which are irritants may also be corrosive to substances other than human tissue. Ammonia gas is the corrosive-irritant that is probably most frequently encountered in industry. Protective clothing and equipment must be used to minimize exposure to corrosive or irritating materials.

Gases that do not react at ordinary temperatures and pressures with other materials are classified as inert. If released in a confined area, inert gases may displace the oxygen content of the air below the level necessary to sustain life. Therefore, asphyxiation (death from lack of oxygen) is the hazard associated with inert products. Adequate ventilation and monitoring of the oxygen content of confined areas minimizes the possibility of asphyxiation. Examples of gases that do not react with other materials are argon, carbon dioxide, helium, and nitrogen.

Toxic materials are those substances that may chemically produce injurious or lethal effects. The degree of toxicity and the effects vary with the compound. Some gases are especially dangerous because they do not provide adequate warning of their presence (by color, odor, and so forth) at low levels of concentration. Also, some products that are nontoxic in themselves may react with certain chemicals or decompose at elevated temperatures to produce toxic materials. One of the most common of toxic gases is carbon monoxide. Adequate ventilation, protective clothing, and suitable breathing equipment must be used to minimize exposure.

Some gases having very low boiling points are stored as liquids in insulated vacuum-jacketed containers known as dewars, or in insulated pressurized cylinders. Contact with these liquids causes "burns" due to the freezing of the skin tissue by the rapidly evaporating liquid. Also, the liquid produces a large volume of gas when it vaporizes. In inadequately ventilated areas, this large volume of gas may decrease the oxygen content of the air below the level necessary to sustain life. Adequate ventilation monitoring of the oxygen content of confined areas and the use of protective clothing minimize the hazards. Examples of materials stored as liquids and classified as "cryogenic" are liquid nitrogen and liquid oxygen.

This module addresses primarily those gases in each category normally found in the industrial setting. The worker should either consult the references listed at the end of this module if other compressed gases are encountered, or contact the supplier of the specific compressed gas prior to use.

ACTIVITY 2:

Match each term in the left-hand column with its description in the right-hand column.

____ 1. Flammable gases.	a. Causes inflammation of human tissue.
____ 2. Oxidants.	b. Death from lack of oxygen.

____ 3.	Corrosives.	c.	Will burn or explode in the presence of air or other oxidants.
____ 4.	Irritants.	d.	In confined spaces, may displace the oxygen in the air, leading to asphyxiation.
____ 5.	Inert gases.	e.	Materials having low boiling points that are stored as liquids in dewars.
____ 6.	Asphyxiation.	f.	Poisonous gases; substances that can chemically produce lethal effects.
____ 7.	Toxic gases.	g.	Materials that corrode or deteriorate materials they contact.
____ 8.	Cryogenic materials.	h.	Materials that support combustion.

OBJECTIVE 3: Identify the differences between low-pressure and high-pressure cylinders as related to use and construction.

Gases exert pressure. Gases actually consist of a large number of extremely small particles, called molecules, that continually fly about in the space they occupy. Any container of a gas will be bombarded by these flying molecules striking the insides of the container walls; thus the gas occupies the space of enclosure. Enough space exists between the molecules in a gas that more gas can be added into a given space and will fit, but at the same time more and more molecules will be hitting the sides of the container. The energy of these bombarding molecules creates pressure. The greater the number of molecules of gas that are present in the container and the faster they move, the higher the pressure. Compressed gases have to be contained in specially built cylinders that are designed to accommodate the pressure of a lot of gas compressed into a relatively small volume. Examples of this kind of container are the acetylene and oxygen cylinders used for the standard oxyactylene welding rig (Figure 1).

The Department of Transportation (DOT) has provided for safe methods of transporting all categories of gases by controlling the design of, shipping and storage containers for gas. Compressed gas cylinders (containing gas at over 25 psig [pounds per square inch gage]) are subdivided into categories of low pressure and high pressure. Any cylinder that is designed to retain gases at a marked service pressure of less than 900 psig is defined as a low-pressure cylinder. Acetylene cylinders with an authorized service pressure of 250 psig are examples of low-pressure cylinders.

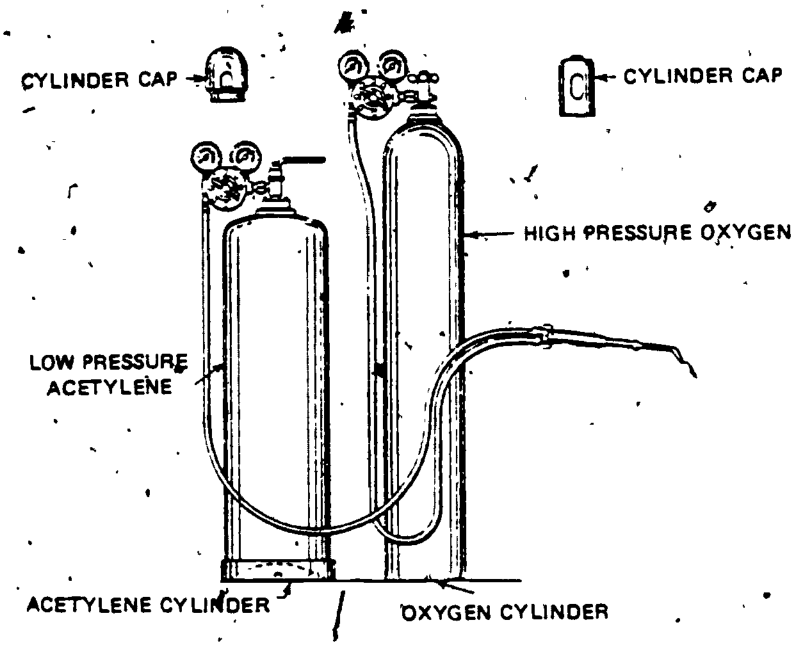

Figure 1. Acetylene and oxygen cylinders in standard oxyacetylene welding rig.

Low-pressure cylinders are usually manufactured from several drawn sections and welded together, as shown in Figure 2. DOT requires that all such construction, whether of cylinders, or tank cars, be performed in accordance with American Society for Mechanical Engineers (ASME)-Unified Pressure Vessel Code. ASME Section IX is used to control all qualifications of process, procedures, and operator qualifications.

DOT also specifies the types of metal that are used for construction and their thickness. Acetylene, MAPP, and propane wall thicknesses range from 0.78 inch to 0.128 inch and usually are either mild steel or chromium moly base metal.

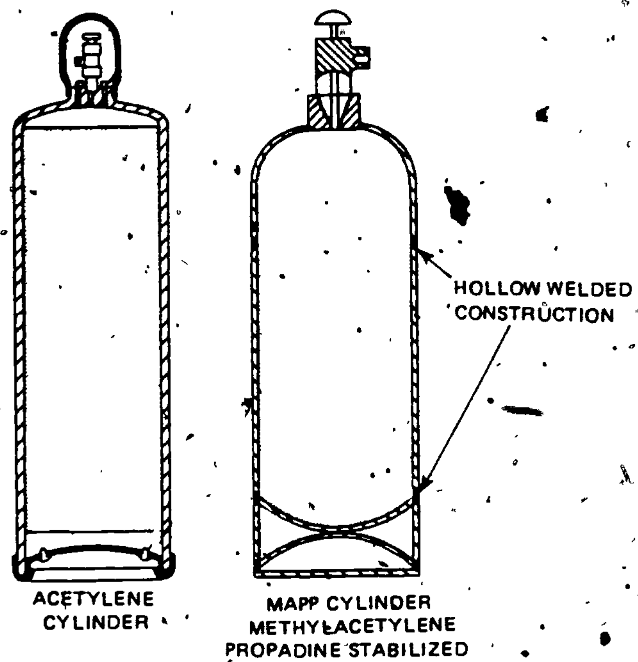

Figure 2. Example of low-pressure cylinder construction.

Cylinders with marked service pressures of 900 psig or greater are defined as high-pressure cylinders. This working pressure will be stamped on the shoulder of the cylinder, as shown in Figure 3. Oxygen cylinders are examples of the high-pressure (2200 psig) cylinders.

High-pressure cylinders are manufactured from a one-piece forging with the neck formed by spinning to shape. The base metal used depends on the DOT specification to which it is manufactured.

Cylinders stamped with DOT 3A 2015 are usually made from manganese steels and have a working service pressure of 2015 psig when measured at 70°F. Cylinders stamped with DOT 3AA and 2400 indicate a cylinder fabricated from higher strength chromium molybdenum steel, heat treated after forming to produce a lighter weight cylinder and a higher working (or service) pressure of 2400 psig minimum when measured at 70°F.

Liquid gas cylinders must not only contain the gas at high pressure, but must also be designed to keep the liquid (such as oxygen or argon) cold. Most liquid gas containers are built like a thermos with high-density insulation.

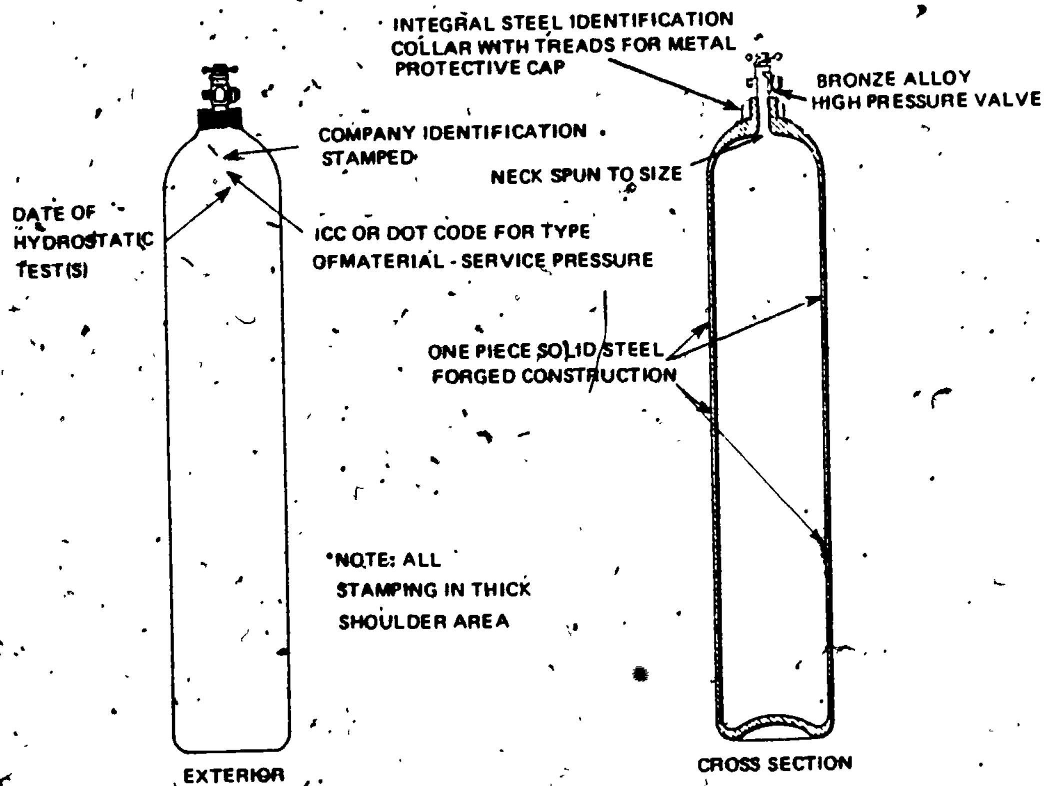

Figure 3. Typical high-pressure cylinder construction.

ACTIVITY 3:

(Fill in the blanks.)

1. The highest pressure cylinders are usually fabricated from ______________________ base metal.
2. High-pressure cylinders are of _____ piece design formed by forging or extrusion.
3. Low-pressure cylinders are fabricated using ______ design to the ___________ Unified Pressure Vessel Code.
4. A cylinder stamped with DOT 3AA would have a service pressure ________ psig.

OBJECTIVE 4: Describe three types of safety-relief devices for compressed gas cylinders.

Most of today's gas cylinders are equipped with some kind of safety-relief device. A safety-relief device can prevent rupture of a cylinder when there is a sudden increase in pressure due to heat buildup. Without a safety-relief device, increased pressure can cause a violent rupture of the cylinder and its being propelled like a rocket at a very high rate of speed. If the pressure is vented into the air gradually by the use of a safety-relief device, the hazard of violent rupture can be avoided.

Three types of safety relief devices in general use today are -

- Safety-relief valves.
- Frangible discs.
- Fusible plugs.

All three are capable of relieving gases, but each one work in a different way.

A safety-relief valve is part of the cylinder. Spring force usually holds the valve in a closed position. When the pressure in the cylinder becomes greater than that of a normally charged cylinder at 150°F, the valve resets itself, opening to release the contents of the cylinder. When enough gas has been released to bring the pressure within safe limits, the valve resets itself, closing until pressure builds up again.

The frangible (easily broken) disc cannot reset itself. As the name suggests, the metal disc is designed to break at a certain pressure and release the contents of the cylinder. Frangible discs are used alone and in combination with safety-relief valves.

A third type of safety-relief valve is the fusible plug. A fusible plug is activated by temperature rather than pressure. Some gases decompose at elevated temperatures, and decomposition results in rupture of the tank. A temperature-activated device is more suitable than a pressure-activated device for these gases.

Compressed gas cylinders use a combination of safety-relief valves, frangible discs, and fusible plugs to prevent cylinder rupture.

ACTIVITY 4:

1. Name the type of safety-relief device than can reset itself. ____________________
2. Name the type of safety-relief device that is activated by temperature. ____________________
3. Name the type of safety-relief device that breaks in order to release gas. ____________________

> **OBJECTIVE 5:** Identify the hazards encountered in handling compressed gas cylinders on the job and state the safety measures required.

A compressed gas cylinder must be capable of being transported hundreds of miles during its working lifetime and of being handled by skilled and unskilled workers. For economic reasons, the DOT and the manufacturer have spent much time and energy designing a light-weight container that allows the maximum number of cylinders to be hauled in each truckload. These organizations have also built in safety features as a protection against accidental rupture. However, the workers must do their part by handling each cylinder using proven safe procedures to protect the cylinder from damage.

The worker should follow certain safe procedures -

1. Only cylinders meeting DOT regulations should be used.
2. Filling or charging of cylinders should be done only by qualified personnel.
3. Gas should never be transferred from one cylinder to another.
4. The gas should always be referred to by its technical name.
5. Cylinder labels should not be mutilated, changed, or removed.
6. When not in use, each cylinder must have its protective cap secured over the cylinder valve.

7. All cylinders should be stored in an upright position.
8. All cylinders must be secured in storage.
9. All cylinders must be secured during transportation - use a suitable hand truck.
10. Cylinders should never be used as rollers, supports, or for any purpose other than to contain the contents as received.
11. Cylinders should not be placed where they might become part of an electric circuit.
12. Cylinders must not be lifted with an electromagnetic crane or by slings, ropes or chains.
13. Lifting by crane should be done only when a suitable cradle or platform is provided. (See Figure 5.)
14. Cylinder valves should always be kept closed.
15. Cylinder must be stored in accordance with appropriate standards.

ACTIVITY 5:

List from memory 10 of the 15 general safety rules dealing with cylinders. (Cover the list above as you work.)

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______
8. ______
9. ______
10. ______

OBJECTIVE 6: Describe the types of cylinder damage and the methods and criteria for periodic inspection.

High-pressure compressed gas cylinders are prooftested by hydrostatic testing at the time of manufacture. During hydrostatic testing, water is pumped into the cylinder to one and a half times the working or service pressure, usually 3360 psig to 4000 psig. The cylinder is evaluated either by reading the amount of liquid displaced from a special external test chamber, or by holding the pressure and checking for any drop in pressure. A drop in pressure would signify a physical expansion (yield) of the cylinder. The amount of allowable yield is controlled by DOT specifications and must be subjected to retesting at either five- or ten-year intervals. Low-pressure cylinders (such as acetylene cylinders) cannot be hydrostatically tested because of their "solid" filled design. All compressed gas cylinders must be subjected to detailed visual tests by the vendor for corrosion, dents, cuts, gouges, digs, fire damage, and arc strikes. Users of these cylinders should also be aware of the visual indications of cylinder damage. Cylinders should be free of any surface contamination, rust, mud, or excessive coatings of paint so that visual inspection can be readily performed.

As each cylinder is delivered from the vendor or selected for use from storage, the worker can readily inspect for obvious damage such as:

- Dents: Dents in areas of welds should not be greater than 1/4 inch deep. Dents not in welded areas should not exceed a depth of 1/10 of the total dent diameter.
- Cuts, Gouges, or Digs: These defects not only reduce the thickness of the cylinder wall, but also act as stress risers. Although the original wall thickness may not be known, a cylinder should not be used in service if the defect exceeds half the minimum allowable wall thickness specified by DOT. Depending on the design criteria, a gouge of 1/32 of an inch deep could be just cause for rejecting a cylinder. Careful handling of cylinders can help to ensure personal safety as well as provide an economical advantage.
- Pits, Line Corrosion: Isolated pitting up to one third of the wall thickness is allowed. However, evidence of line corrosion that exceed three inches in length or pits that exceed 3/64 of an inch in a general corrosion area should be grounds for removing the cylinder from service. This type of defect is prevalent on the bottom of cylinders that have been set on wet ground. Extensive corrosion can also be checked for by weighing the cylinder before it is filled by the vendor. Any cylinder that weighs less than 95% of its original tare (empty) weight should be rejected.
- Evidence of fire damage, arc strikes, or obvious bulges are cause for removal of cylinders from service, as are obvious distortion valves.

The worker should advise the immediate supervisor or the vendor upon discovering such defects.

ACTIVITY 6:

(Fill in the blanks.)

1. The DOT controls the acceptance of high-pressure cylinders by ______________ testing on a periodic basis.
2. Although the vendor is responsible, the workers should visually inspect each cylinder they use for defects such as:
   a. ______________
   b. ______________
   c. ______________
   d. ______________
   e. ______________

OBJECTIVE 7: Describe the types of storage areas acceptable for safe storage of compressed gas cylinders.

Cylinders should be stored in a definitely assigned location that possesses or allows the following physical conditions to exist:

1. Full and empty cylinders should be stored separately. Empties should be marked "MT" with chalk.
2. All cylinders must be secured in upright position.
3. Storage areas should be dry, cool, and well ventilated.
4. Cylinders should not be stored near radiators or other sources of radiant heat.
5. Sparks and flames must be kept away from cylinders.
6. Cylinders should not be stored near highly flammable substances such as oil, gasoline, waste, and so forth.
7. Flammable gases must not be stored within 20 feet of oxygen unless they are separated by a noncombustible 5-foot high wall with half an hour fire resistance.

8. Protective caps should be on all cylinders except when in use.

9. Cylinder valves should be kept closed on empty cylinders.

10. Indoor storage of fuel gas should be limited to a total capacity of 2000 cubic feet or 300 pounds of liquefied petroleum gas.

11. Cylinders must not be kept in unventilated enclosures such as lockers and cupboards.

12. Cylinders should be kept away from stairs, elevators, or gangways where movement of equipment may cause damage, or where items may be dropped onto cylinders.

13. Cylinders should be stored on a level, fireproof floor.

14. Cylinders should be protected from extremes of weather, accumulations of ice, snow, or continuous, direct, summer sun rays.

15. Cylinders should never be subjected to temperatures approaching 130°F.

16. Direct flame or electric arc should never be allowed to contact any part of a cylinder.

17. In storage areas, smoking should not be allowed. No source of ignition should be permitted. Wiring should be in conduits and lights should be enclosed. Electric switches should be located outside the room.

Workers on construction sites will have to expend extra effort in ensuring the specific storage criteria are met. The need for safe handling of cylinders and for guarding against cylinder damage is often hard to accomplish on construction sites. The safety of others who may handle the cylinders months later is still the responsibility of each worker.

ACTIVITY 7:

1. List the storage criteria for empty cylinders.
   a. ____________________
   b. ____________________
   c. ____________________

2. List the storage criteria for fuel gas cylinders.
   a. ____________________
   b. ____________________
   c. ____________________
   d. ____________________
   e. ____________________

OBJECTIVE 8: Name the types of vehicles and containers that are widely used in the transport of compressed gases.

Gases may be shipped by highway, rail, waterway, or air. By rail, gases travel in tank cars or TMU cars (ton multi-unit, or ton containers). Rail tank cars are large pressure tanks with a capacity ranging up to 10,000 gallons for compressed gases and up to 60,000 gallons for liquefied petroleum products. These tank cars are built either insulated or noninsulated and can accommodate a maximum pressure of 600 psig.

The TMU is a flat bed rail car with fifteen cylinder tanks, which accommodate pressures from 500 to 1000 psig. TMU containers used to store liquefied gases are equipped with two valves, one for vapor and one for liquid, each of which is protected against damage by a hood. Sometimes TMU units have fusible plugs that melt at temperatures between 155°F - 165°F.

Three main types of vehicles are used for carrying compressed gases on the highway: cargo tanks, portable tanks, and tube trailers. Cargo tanks are mounted on small truck frames or on the larger beds of semitrailers. Some cargo tanks are provided with cooling coils; others are merely insulated.

Portable tanks, long cylinders with two legs on each end, are available in many sizes (from 120 gallon to 2000 gallon volume) and with a capacity for various pressures (from 100 psig to 500 psig).

Tube trailers can be used to store gases at higher pressures - up to 2000 psig. These semitrailers carry a series of cylinders (tubes) all joined together at a common head.

ACTIVITY 8:

1. State why TMU containers used to store liquefied gases are equipped with two valves. ____________

____

2. Which type of vehicle is used to store gases at pressures up to 2000 psig? ______________________

____

OBJECTIVE 9: State the classification of gas contained in a cylinder or tank by identifying the DOT label.

The classification and marking of compressed gas cylinders and tanks is required by government regulations under the control of the Department of Transportation and the Occupational Safety and Health Administration (29 CFR 1910, Subpart Q). Two standards organizations have been involved in the setting of these standards: American Welding Society and American National Standards Institute (Z48).

Each compressed gas cylinder must be readily identifiable as to content. This identification is by color code, or by lettering that states the category of gas, names the content, and gives a brief statement of hazard.

Shown in Figure 4 are typical examples of labels the worker should look for before using the contents of any cylinder.

Manufacturers and distributors may elect to help the worker identify the cylinder contents by painting either the cylinder neck ring or the complete cylinder the correct color for the gas contained (Table 2). However, the worker should be aware that checking the label is the only sure means of gas identification.

The student and worker should remember that even nonflammable gases can be hazardous. Oxygen of high purity and at the high concentration available at the compressed gas valve can cause instantaneous combustion (explosion) in the presence of oil, grease, and coal dust. Oxygen supports combustion so violently that it must be kept away from all combustibles.

Gases such as argon, although inert (nonreactive), can displace the breathing air in confined areas and cause asphyxiation.

Compressed gas cylinders displaying skull and crossbones (poison), acute toxicity, or radioactive labels should not be handled without special training and equipment.

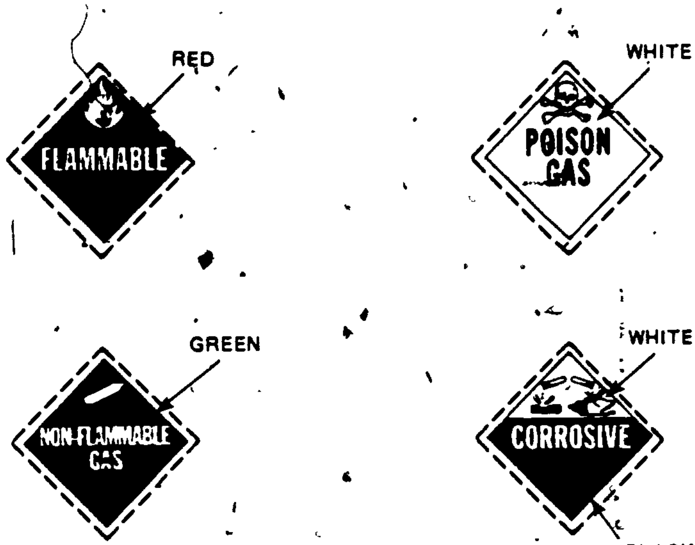

Figure 4. Typical DOT labels for compressed gases.

TABLE 2. TYPICAL COLOR CODE.

Compressed Gas	Class	Label	Typical Cylinder Color
Acetylene	Flammable	Red	Red-Black-Gray-Orange
MAPP®	Flammable	Red	Yellow
Oxygen	Nonflammable	Green	Green-gray
Argon	Nonflammable (inert)	Green	Brown
Air	Nonflammable	Green	Cream
Helium	Nonflammable (inert)	Green	Brown
Hydrogen	Flammable (very)	Red	Red
CO_2	Nonflammable (semi-inert)	Green	Silver
Phosphine	Poison	White	Red (Skull and Crossbones)

The Department of Transportation labels shown in Figure 4 are used to identify the contents of tank cars, tube trailers, and TMU cars as well as for cylinders.

ACTIVITY 9:

(Circle either True or False.)

1. A red DOT label indicates a flammable compressed gas is contained in that cylinder.

   True   False

2. A green DOT label indicates a nonflammable compressed gas, and no safety hazards are associated with these gases.

   True   False

3. Although some manufacturers do color code their cylinders, the worker can be sure only of the label.

   True   False

4. One should never remove or intentionally mutilate the label on a cylinder.

   True   False

5. A white label indicates pure, hazard-free gas.

   True   False

OBJECTIVE 10: Explain the effect of heat on gas cylinders and tanks containing flammable gases.

Many gases are stored and transported in steel cylinders. Oxygen, hydrogen, nitrogen, air, and other gases that are available in cylinders should be handled with caution: stored upright, secured to a fixed structure, and protected from high temperatures.

If a gas enclosed in a cylinder is heated so that its temperature rises, the pressure of the gas will also increase. As long as the temperature of the gas does not rise above 125°F, the gas is assumed to be safe. If the gas does exceed this temperature (and even the sun's rays can produce enough heat to do this), the cylinder is likely to burst, usually near its valve, and will have all the force and deadly nature of a unguided missle. The danger associated with ruptured cylinders includes the high speed with which they are propelled by escaping gas as well as the explosion and flame of flammable gases.

When tanks containing highly flammable gases under pressure are exposed to flames, as frequently occurs during rail and truck accidents, a similar hazard exists. Gases shipped in tank cars often separate into two phases, a heavy liquid phase at the bottom of the tank, and a gaseous phase in the area above. If flames resulting from the puncture of a nearby gas tank contact the tank car containing flammable gas, the flammable gas tank shell will be weakened and the liquid may begin to boil. The pressure can become so great that even a venting mechanism in the tank cannot relieve it quickly enough to avoid explosion. This type of explosion is known as a BLEVE (pronounced "blevey"); the letters stand for Boiling Liquid Expanding Vapor Explosion. A BLEVE can take place from ten to thirty minutes after flames first come in contact with the tank car. A BLEVE results in enormous destruction from the initial fire and explosion, secondary explosions, as well as flying fragments of the tank.

ACTIVITY 10:

BLEVE stands for ______________ ______________.

______________ ______________ ______________.

OBJECTIVE 11: Identify the particular hazards of oxygen, acetylene, MAPP gas, natural gas, liquefied petroleum gas, chlorine, ammonia, hydrogen, carbon dioxide, and fluorine.

Certain gases are in frequent use in many different fields, and have a number of hazards associated with them. The hazards of some of these gases are reviewed under this objective.

OXYGEN

Oxygen is used with acetylene for welding; to assist breathing, to stimulate the heart, and to aid in other treatments in the medical field; and to increase the efficiency of blast furnaces.

Although oxygen supports combustion, it does not burn. Oxygen is considered a hazardous element because flammable materials burn much faster in oxygen, and oxygen can quickly combine with other elements and compounds to produce spontaneous ignition. When oxygen comes into contact with oil, grease, or fuel oils, the result can be a sudden and violent fire. Employees involved in the handling of this gas must take every precaution to prevent the combination. Liquid oxygen can be equally dangerous if not handled properly. A burning cigarette dropped into liquid oxygen will produce a flame two feet high, and even shredded metal will burn if exposed to it. Open flames and smoking must never be allowed near oxygen storage areas.

ACETYLENE

Acetylene is used with oxygen in welding and cutting operations. Acetylene is also used in the manufacture of plastics, organic compounds such as acetic acid and acetone, drycleaning solvents, paints, synthetic fabrics, and Plexiglas.

Acetylene has the widest flammable range known and is classified as an asphyxiant. Under certain conditions, it can form compounds with silver, copper, and mercury that explode spontaneously. Acetylene is stored in cylinders at a pressure of 250 psig. The cylinders contain a porous material and acetone to absorb acetylene in a stabilized condition.

MAPP GAS

MAPP gas refers to methyl acetylene propadiene, a stable liquefied petroleum gas that is used as a substitute for acetylene. MAPP is not as shock sensitive or as flammable as acetylene.

NATURAL GAS (METHANE)

Methane is the major constituent in natural gas. In addition to being flammable (its high heat of combustion is what makes it desirable as a heating fuel), methane works as an asphyxiant by excluding oxygen from the lungs. Therefore, a methane atmosphere can be deadly in a confined area as it causes suffocation, but methane is not toxic.

Small amounts of ethane and propane are also contained in natural gas. In addition, a chemical called mercaptan is added in extremely small amounts to give a warning odor to natural gas.

Natural gas is usually compressed and sent through pipelines. Broken pipes are one type of natural gas emergency. Leaks can occur indoors or outdoors, and must be dealt with immediately. It is important to realize that if a leak has not ignited yet, it can at any moment.

The following procedures should be observed in the case of a gas leak:

- Notify gas company.
- Evacuate the area or building.
- If outdoors, eliminate ignition sources and then shut off the supply of gas.
- If indoors, shut off the supply first, then eliminate the ignition sources, and ventilate the building.
- Stand by at a distance.

Follow these procedures if a fire has already begun:

- Notify the gas company.
- If outdoors, allow the gas to burn and evacuate the area. Protect surrounding exposures and stand by at a safe distance.
- If indoors, shut the supply off, then extinguish the fire and/or protect the surrounding area until the gas supply is off.

LIQUEFIED PETROLEUM

Although they are nontoxic and noncorrosive, the two widely used liquefied petroleum gases, propane and butane, are hazardous because of their freezing capacity and their flammability. BLEVES (discussed in Objective 10) have occurred during the transport of LP gas.

Propane and butane leaks can be detected by the odor of mercaptan. Liquid propane creates a vapor cloud as it converts to a gas. The important actions to take regarding a leak are to notify authorities, avoid contact with the escaping gas, stop the flow of gas if possible, and keep all ignition sources away.

CHLORINE

Chlorine, a greenish-yellow gas with a strong, unpleasant odor, is found around water treatment plants, swimming pools, and other areas where bacteria control is carried out.

Chlorine is not flammable, but it can react with organic compounds such as petroleum products, ethers, and alcohols with explosive violence. It is a toxic, corrosive, very irritating gas. If mixed with acetylene, it will explode when exposed to sunlight. Never use water on a chlorine leak. Only slightly soluble in water, chlorine reacts with water to form hypochlorous and hydrochloric acids which eat into iron and steel. Iron and steel are not affected by dry chlorine at lower temperatures; however, those metals used in chlorine systems must be kept dry at all times.

Chlorine leaks must be handled with extreme caution. A tipped chlorine gas cylinder must be set upright so that gas and not liquid escapes (much more chlorine gas will be formed if the liquid is allowed to leak). Fire fighters should wear self-contained breathing apparatus. Caustic soda, soda ash, or hydrated lime may be used as a neutralizer of chlorine. Water only produces corrosive hydrochloric acid. Any large chlorine leak requires evacuation of the immediate area.

AMMONIA

Ammonia is colorless, lighter than air, has a piercing odor, and is highly irritating to the eyes, skin, and respiratory tract. The National Institute for Occupational Safety and Health (NIOSH) lists 81 occupations with potentially hazardous exposures to ammonia. They range from acetylene workers and farmers to tanners and wool scourers. The substance is widely used as a fertilizer and refrigerant.

Anhydrous ammonia is the pure dry gas. Liquid anhydrous ammonia is this gas compressed into a liquid. Ammonium hydroxide is gaseous ammonia dissolved in water. Anhydrous ammonia is flammable, and though its flammable range is very high, ammonia fires and explosions are not uncommon. The chief hazard of ammonia are freeze burns, severe eye injury, and death from inhalation of high concentrations. In industrial plants and other workplaces, unauthorized employees must never enter ammonia-hazard areas. Gas masks and other protective equipment must be located within easy reach. In the event of ammonia exposure, the skin and eyes of the victim should be immediately flushed with plenty of potable water, and medical attention must be sought at once. Employees authorized to handle anhydrous or strong aqua ammonia must wear gloves, shoe covers, and aprons that are impervious to ammonia. They must also wear eye and face protective equipment.

HYDROGEN

Hydrogen, the lightest of all elements, is both colorless and odorless. Its flammable range is almost as wide as that of acetylene. A mixture of 10 to 65 percent in air will explode if ignited. Hydrogen is classified as an asphyxiant.

Some chemical reactions produce hydrogen as a byproduct. A lead-acid battery will produce hydrogen when being charged. Many electroplating processes also produce hydrogen. Some chemicals used to remove scale from the water side of boilers manufacture hydrogen. Whatever the operation, it is important to know whether hydrogen will be produced, and measures must be taken to prevent its accumulation and ignition. This is accomplished by proper ventilation and elimination of possible sources of ignition.

Storing hydrogen is difficult. This gas tries to find its way out of confinement and will seek the smallest opening in a pipe or container. Pipe threads and stems must be tight, because a high pressure hydrogen leak can ignite spontaneously, the cause being the friction of its own escape. All flammable gas leaks are dangerous and particularly so when, as in the case of hydrogen, they can be neither seen or smelled.

CARBON DIOXIDE

Carbon dioxide, which is odorless, colorless, and heavier than air, is toxic when high percentages are present and can cause death when encountered in asphyxiating concentrations. This gas is not flammable and is in common use as a fire extinguishing agent. Because of its ability to displace oxygen, it will smother the fires of petroleum, coal, and wood; but the fires of magnesium, sodium, potassium, and metal hydrides will burn rapidly in an atmosphere of carbon dioxide.

FLUORINE

Fluorine is a pale yellow, corrosive, and poisonous gas that attacks all but a few materials. Fluorine and acetylene mixtures also may explode if exposed to light.

ACTIVITY 11:

1. Name at least one hazard associated with each of the gases listed.
   a. Oxygen ____________
   b. Acetylene ____________
   c. Methane ____________
   d. Liquefied petroleum ____________
   e. Chlorine ____________
   f. Hydrogen ____________
2. Mark the following statements true or false.
   ____ a. A chlorine liquid leak will result in much more vapor forming than a chlorine gas leak.
   ____ b. Methane can be classified as a toxic gas.
   ____ c. Methane is the major constituent of natural gas.
   ____ d. Oxygen will burn readily.
   ____ e. Acetylene has the widest flammable range known.

OBJECTIVE 12: Identify three main hazards associated with cryogens and tell the particular hazards associated with liquid oxygen, liquid fluorine, and liquid nitrogen.

Gases can be converted to liquids by a decrease in temperature, an increase in pressure, or both. Each gas has a certain temperature, called the critical temperature, above which pressure alone cannot condense the gas to liquid form. For example, carbon dioxide can be changed from a gaseous to liquid form if sufficient pressure is applied while the gas is below 88°F. If the gas goes above 88°F, no amount of pressure will be sufficient to liquefy the gas. Gases that must be cooled to less than -150°F to bring about this liquefication (that is, their critical temperature is below -150°F) are called cryogens. For example, hydrogen, oxygen, and methane are classified as cryogens because each of these substances must be cooled to below -150°F before converting to a liquid.

Cryogenic techniques are applied to many industrial and medical situations. With cryogenic gases, food can be flash frozen; blood can be stored for long periods of time; electrical power can be distributed more economically. Steel mills, hospitals, and aerospace companies have improved operations through the use of cryogenic gases. Many gases that used to be transported in compressed gas form are now handled efficiently and at a savings in a liquid form. The increased economy associated with transportation and storage of cryogenic gases is accompanied by several new hazards.

Cryogens are stored in double-walled glass containers known as Dewar flasks. Special care is required in the handling of cryogens; three main hazards must be considered: a high expansion rate on vaporization, an ability to liquefy other gases, and a potential to damage living tissue.

Cryogens have a high expansion rate when they vaporize. For example, liquid methane expands to 630 times its liquid volume when it vaporizes. If the cooling mechanism should fail for any reason, the resulting expansion of gas would create tremendous pressure within the storage container. Proper venting devices must be provided in case of such an occurrence.

Since cryogenic fluids are extremely cold, they have the capacity to liquefy and even solidify other gases. In situations where rapid expansion is taking place (as mentioned in the above paragraph), the solidifying of air by escaping gas is a serious problem. If air is solidified in the venting tubes of storage containers, then the venting passage will be blocked and no release of pressure will be able to take place.

Cryogen contact can be damaging to living tissue, just as hot burns are. Not only skin tissue is damaged by the extreme cold of a splashing cryogenic fluid, but local circulation of blood may be stopped, also. The real danger of arrested circulation lies in the possibility of blood clot formation as the tissue thaws. Skin tissue that has been exposed to cryogenic fluids should be restored to normal temperature as soon as possible by immersing the affected area of the body into water around 108°F. Personal protective equipment (PPE) must be worn by workers handling cryogens. PPE should include splash goggles, face shields, gloves and protective clothing.

Certain cryogenic gases with a high hazard potential are discussed below.

LIQUID OXYGEN

Liquid oxygen, known as LOX, is hazardous in several ways. Because it supports combustion, most all combustible organic materials burn in its presence. Combustible organic material includes thousands of substances in everyday use, such as grease, oil, wood, cloth, even asphalt.

Protective clothing must be worn to cover the whole body when workers are handling LOX. Any clothing that becomes contaminated with oxygen should be kept away from any ignition source and removed from the wearer as soon as possible. LOX burns should be treated immediately in water around 108°F; then qualified medical help should be sought.

LOX fires are more intense than most fires. If possible, the flow of LOX should be stopped as a first step in controlling the fire. Water spray may then be used, but care should be taken not to spray water on safety-relief devices, since they can be blocked by ice.

LIQUID FLUORINE

Fluorine is extremely toxic and corrosive, as well as being an oxidizer. Fluorine will burn in combination with many substances, and even reacts with concrete and steel, thus having to be contained in special, high-purity steel containers. Fluorine can cause both cryogenic and chemical burns.

LIQUID NITROGEN

Liquid nitrogen does not support combustion, so its hazard potential is less than that of liquid oxygen and liquid fluorine. The greatest danger associated with its use are freezing and sudden expansion. Sudden expansion can cause asphyxiation (death due to lack of air) if a liquid nitrogen container ruptures in a closed space. One cubic foot of liquid nitrogen can expand to 681 cubic feet of vapor!

LIQUID HELIUM

Liquid helium, the coldest of the cryogenic gases, is used as a cooling medium for nuclear reactors and as protective layer for electronic work. Freezing is one hazard associated with helium.

LIQUID HYDROGEN

Hydrogen is highly flammable, and therefore extreme precuations must be taken in its handling.

LIQUID NATURAL GAS

In its liquid form, natural gas is odor-free. The substance mercaptan that is added to it to create an odor warning is added after the liquid is vaporized. Also, as natural gas forms a vapor from its liquid state, it is colder and heavier than air. These factors should be known to those who may have to fight a liquid natural gas fire.

ACTIVITY 12:

1. List three main hazards associated with cryogenic gases:
   a. ______
   b. ______
   c. ______
2. The tendency of cryogens to liquefy or solidify other gases can be a problem because -
   a. If air in venting tubes is solidified, the venting tubes will break.
   b. If air in venting tubes is solidified, venting cannot take place.
   c. If air in venting tubes is solidified, rapid expansion cannot take place.
   d. All of the abve are true.
3. Rapid expansion of vapor can cause -
   a. Asphyxiation in a closed container.
   b. Tremendous pressure within a storage unit.
   c. Rupture of a storage unit.
   d. All of the above are true.

OBJECTIVE 13: Explain the difference between medical-use and industrial-use gases and give five examples of medical uses for gases.

Medical-use gases are different from industrial-use gases only in their degree of purity. While the impurities of regular compressed gases are measured in parts per hundred, impurities in medical gases are measured in parts per million.

A number of compressed gases have an important role in medical treatment. Oxygen is used to assist breathing in oxygen tents and masks. Nitrous oxide, better known as laughing gas, is an anesthetic agent. Helium is used in conjunction with oxygen in treating obstructive lung disease. Cyclopropane is a general anesthetic, but because it is highly explosive when mixed with oxygen, it is not commonly used. Carbon dioxide is used in certain abdominal diagnostic tests, and in concentrations of 5% to 95% oxygen is used to clear hyperventilation.

The handling and storage precautions for medically applied compressed gases are similar or identical to those required for other compressed gases.

ACTIVITY 13:

1. Complete the statement:
   The main difference in gases used for medical purposes and gases used for industrial purposes is the
   ______________________________.

2. Name five gases that have medical applications and tell one way in which each is used.
   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________
   e. ______________________________

OBJECTIVE 14: Describe the general safety hazards in using compressed air.

Compressed air, similar to that used to inflate automobile tires, has found many uses in industry as power for pneumatic wrenches, staple guns, grinders, drills, and many other standard tools. Although air does not have the shock potential of electric tools or the explosive nature of arcs, air must be used carefully.

One of the most common uses of air, cleaning parts, should be re-evaluated. Whenever possible, workers should consider the use of vacuum methods to cut down on air contaminants and keep from blowing foreign matter into their eyes. If compressed air must be used for cleaning, the pressure must be limited to 30 psig.

The compressed air pressure required for many pieces of equipment are 80 to 90 psig. Air at these pressures can become a hazard if an air hose ruptures, or if another workers pulls or breaks the line by tripping over it, or if a splice lets go. The air hose will whip violently and could cause injury unless the air valve is shut off quickly.

Horseplay with compressed air can cause rupture of the ear drums, and the injection of air into any body orifice or skin puncture can cause fatal or irreparable damage.

To safeguard against accidental starting of air equipment, hand-operated interlocks that require both hands to be on the equipment are sometimes used. Regulators for reducing line pressure from up to 125 psig to 30 psig for general cleaning nozzle work are recommended. Pressure relief devices such as shown in Figure 5 are also commonly used for safety measures.

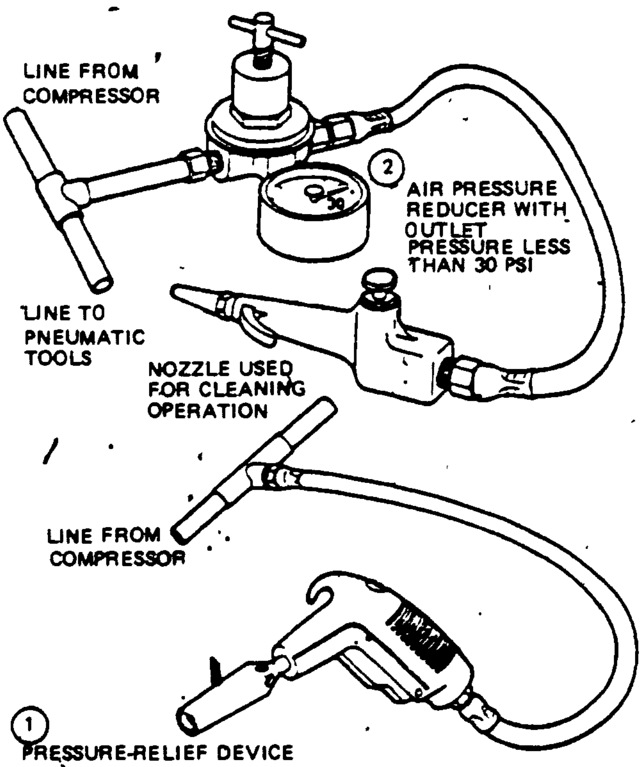

Figure 5. Pressure relief devices.

Tanks that hold compressed air are called receivers. These receivers must be manufactured in accordance with the American Society of Mechanical Engineers (ASME) Pressure Vessel Code Div I Section VIII; or must have a name-plate indicating the manufacturer and the test pressure. All safety relief valves, piping, and compressors must comply with ANSI B19 (Safety Code for Compressed Air Machinery and Equipment).

The welder should never alter or weld on a receiver. Drains should be located so moisture can be readily removed from the system to limit corrosion.

Compressed air is sometimes supplied in portable high-pressure cylinders (2200 psig). These cylinders must be treated with the same respect as other high-pressure compressed gases. To ensure that air is not confused with oxygen, use black hoses for air and green hoses for oxygen. The use of oxygen in air tools that are lubricated with oil will cause the air (pneumatic) tool to explode.

ACTIVITY 14:

(Fill in the blanks.)

1. Pneumatic tools using compressed air for a power source will not cause __________ as will electric power tools.
2. Air pressures in excess of ______ psig should not be used for cleaning.
3. If an air hose breaks, _____________ the supply of air before trying to grab the hose end.
4. ____________ with an air hose could be fatal.
5. Air receivers should not be altered because they have been specifically designed and fabricated to ____________ Code Div. I Sect. VIII.
6. Use of oxygen in a pneumatic tool can cause ______________.

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ANSWERS TO ACTIVITIES

ACTIVITY 1

1. 25 psig.
2. Liquid, cryogenic.

ACTIVITY 2

1. c.
2. h.
3. g.
4. a.
5. d.
6. b.
7. f.
8. e.

ACTIVITY 3

1. Chromolly.
2. One.
3. Welded - ASME.
4. 2400.

ACTIVITY 4

1. Safety-relief valve.
2. Fusible plug.
3. Frangible disc.

ACTIVITY 5

Any 10 of the 15 rules given on pages 12 and 13.

ACTIVITY 6

1. Hydrostatic.
2. Any five.
   a. Bulges.
   b. Pits.

c. Cuts.

d. Gouges.

e. Digs.

f. Dents.

ACTIVITY 7

1. a. Separate from full cylinders.

   b. Away from external heat.

   c. Well ventilated area.

2. a. Away from sparks and flames.

   b. Flammable substance.

   c. Stored upright.

   d. Dry and cool.

   e. At temperatures below 130°F.

ACTIVITY 8

1. One is for liquid leaks and one is for venting of gases.

2. Tube trailers.

ACTIVITY 9

1. True.

2. False.

3. True.

4. True.

5. False.

ACTIVITY 10

Boiling Liquid Expanding Vapor Explosion.

ACTIVITY 11

1. a. Supports combustion.

   b. Extremely flammable, asphyxiant, will explode in certain compounds. (Any one.)

   c. Flammable, asphyxiant (any one).

   d. Have freezing capacity, explosive (any one).

   e. Toxic, corrosive, explosive (any one).

   f. Flammable, asphyxiant (any one).

2. a. True.
   b. False.
   c. True.
   d. False.
   e. True.

ACTIVITY 12

1. a. High expansion rate.
   b. Ability to liquefy other gases.
   c. Ability to damage living tissue.
2. b.
3. d.

ACTIVITY 13

1. Degree of purity.
2. a. Oxygen - to assist breathing (masks and tents).
   b. Nitrous oxide - anesthetic.
   c. Cyclopropane - anesthetic.
   d. Helium - treating obstructive lung disease.
   e. Carbon dioxide - certain abdominal diagnostic tests.

ACTIVITY 14

1. Shock.
2. 30.
3. Shut-off.
4. Horseplay.
5. AMSE.
6. Explosion.